

Appl. No. 10/656,080  
Amdt. Dated December 10, 2005  
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of November 30, 2005

**Amendments to the specification:**

Please delete the first two paragraphs in the "Advantages of the invention" section, that is, on page 3, line 10, the paragraph that begins with "The object as defined. . ." and on page 3, line 15, the paragraph that begins with "Advantageous refinements and..."

Please delete the "Drawings" section which begins on page 9, line 30, and replace it with the following amended section:

**Drawings**

The invention will be explained in more detail in the following text with reference to the associated drawings, in which:

Figure 1A shows a plan view of a first embodiment of a main rotor of the aircraft according to the invention;

Figure 1B shows a side view of Figure 1A in direction A;

Figures 2A to 2C

show examples of electrical drive profiles for adjusting angles of incidence;

Figure 3A shows a plan view of a second embodiment of a main rotor of the aircraft according to the invention;

Figure 3B shows a side view of Figure 3A in direction A;

Figure 4 shows a side view of a push rod arrangement for transmitting a force for adjusting an angle of incidence;

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Figure 5A shows a plan view of a third embodiment of a main rotor of the aircraft according to the invention;

Figure 5B shows a side view of Figure 5A in direction A;

Figure 6A shows a plan view of a fourth embodiment of a main rotor of the aircraft according to the invention;

Figure 6B shows a side view of Figure 6A in direction A;

~~Figure 1a shows a plan view and side view of a first embodiment of a main rotor of the aircraft according to the invention;~~

~~Figures 1bi to 1biii~~

~~show examples of electrical drive profiles for adjusting angles of incidence;~~

~~Figure 1c shows a plan view and side view of a second embodiment of a main rotor of the aircraft according to the invention;~~

~~Figure 1d shows a side view of a push rod arrangement for transmitting a force for adjusting an angle of incidence;~~

~~Figure 1e shows a plan view and side view of a third embodiment of a main rotor of the aircraft according to the invention;~~

~~Figure 1f shows a plan view and side view of a fourth embodiment of a main rotor of the aircraft according to the invention;~~

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Please delete the "Description of the exemplary embodiments" section which begins on page 10, line 24, and replace it with the following amended section:

**Description of the exemplary embodiments**

The exemplary embodiment will be described in the following text for an ultralight model helicopter, by way of example.

Figures 1A and 1Ba shows a plan view and side view of a first embodiment of a main rotor of the aircraft according to the invention. Two coils 106, which are electrically connected via tap contacts (which are not illustrated), are mounted symmetrically with respect to the main rotor shaft 108 on a main rotor plate 103, which is connected to a main rotor shaft 108 which runs in bearings. Two rotary bearings 102 are likewise mounted on the main rotor plate 103 and each have a connecting bracket 101 mounted in them, to whose opposite ends a permanent magnet 105 and a rotor blade 104 are attached. The permanent magnet 105 is arranged such that a direct current 107 through the coils 106 leads to deflection of the connecting bracket 101 and hence to a change in the angle of incidence  $\alpha$  of the rotor blades. The change in the angle of incidence  $\alpha$  also results in a change in the speed of the air which is accelerated downward or upward by the rotor blades 104 as the rotor head rotates, and hence also results in a change in the lift produced by the structure. If the coil current 107 is interrupted again, the centrifugal force on the connecting bracket 101 and on the permanent magnet 105 which is attached to it, as well as the forces which act on the rotor blades 104 counteract the acceleration of the air in the reflection, so that the connecting bracket 101 is reset back to a neutral position. Overshooting is largely prevented by the damping characteristics of the rotor blades 104.

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Overshooting can be virtually completely prevented by fitting a damping but flexible stop 109 on the main rotor plate 103 underneath the connecting bracket 101. By fitting a flexibly elastic element 113 which connects the connecting brackets 101, centrifugal forces which act radially with respect to the rotation axes of the rotor blades and are caused by the connecting brackets 101 can be absorbed, thus reducing the friction in the rotary bearings 102. This design allows the following measures to be used to control a main rotor 100. Application of a direct current 107 to the coil 106 makes it possible to permanently change the deflection of the rotor blades 104 and hence the magnitude of the lift (collective blade pitch) which is coaxial with respect to the main rotor shaft 108. By applying an AC voltage, whose period is synchronized to the speed of rotations of the main rotor shaft 108, a constant lift vector can be produced, which is no longer coaxial with respect to the main rotor shaft 108 but comprises a coaxial lift component (collective blade pitch) and a horizontal drive (aircraft pitch and roll) at right angles to it. The structure is thus provided with the same degrees of freedom of movement as conventional main rotor control systems, but the direct drive components have means ~~that it has~~ considerably less inertia and can thus be actuated more quickly than servo-based rotor control systems.

Figures ~~2A1bi~~ - ~~2C1biii~~ show examples of electrical drive profiles for adjusting angles of incidence. The collective blade pitch drive is provided by a uniform pulse sequence for both rotor blades, as is shown in Figure ~~2A1bi~~. In order to produce smooth, low-vibration running, the pulse sequence should have a period duration which is small in comparison to the time which is required to move a rotor blade 104 from the rest/normal position to maximum pitch and back to the rest/normal position. The aircraft pitch/roll drive can be

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provided by the two rotor blades 104 repeatedly having pulses of opposite polarity applied to them in synchronism with a specific time within the period duration T of the main rotor 100, as is shown in Figure ~~2B1bii~~. The duration of these pulses governs the intensity of the aircraft pitch/roll forces. In order to achieve collective blade pitch and aircraft pitch/roll actuation at the same time, the collective blade pitch and aircraft pitch/roll pulses should not simply be superimposed with aircraft pitch/roll priority, since this leads to interactions between the collective blade pitch and the aircraft pitch/roll. This is due to the fact that, in the case of a rotor blade in which the collective blade pitch and aircraft pitch/roll pulses are in the same direction, the aircraft pitch/roll effect is considerably less than in the case of a rotor blade in which the collective blade pitch and aircraft pitch/roll pulses are in opposite directions. In order to ensure the maximum aircraft pitch/roll control capability and nevertheless to provide independent collective blade pitch and aircraft pitch/roll drive, the pulse sequence for the collective blade pitch must be changed such that the vertical lift remains constant when the aircraft pitch/roll pulses are added. This can be achieved relatively easily by lengthening the collective blade pitch pulses applied to the rotor blades 104, as is illustrated by the dashed line in Figure ~~2C1biii~~.

Figures 3A and 3B1e shows a plan view and a side view of a second embodiment of a main rotor of the aircraft according to the invention. In order to avoid sliding contacts, which in some circumstances are susceptible to defects, for producing an electrical connection to the coils 106, the coils 106 are mounted in the non-rotating part of the helicopter in the embodiment illustrated in Figures 3A and 3B1e. The connection between the rotor blades 104 and the permanent magnets 105 is

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in this case provided via connecting brackets 101, eyes 110 and push rods 111, on which the permanent magnets 105 are mounted. The vertical force which is introduced into the connecting bracket 101 through the push rod 105 via the eye 110 leads to the already described deflection of the connecting bracket 101 and to the described control response, that is to say to the adjustment of the angle of incidence  $\alpha$ . In the embodiment illustrated in Figures 3A and 3B1e, the resetting of the rotor blades 104 is ensured by providing weights 112 instead of the weight of the permanent magnet 105, which is located virtually on the rotation axis.

Figure 41d shows a side view of a push rod arrangement for transmitting a force for adjusting an angle of incidence. The illustration shown in Figure 41d can in particular be combined with the embodiment illustrated in Figures 3A and 3B1e. According to the illustration in Figure 41d, the two permanent magnets 105a, 105b are attached to the ends of two push rods 111a, 111b, which can easily be moved in one another. The thin push rod 111b is driven by magnetic force, by the permanent magnet 105b which is attached to its end, by a current flow through the coil 106b, which is arranged coaxially with a sliding bearing 115b. This applies in an analogous manner to the thicker push rod 111a, which is in the form of a tube and which guides the thinner push rod 111b in the axial direction. This structure has the major advantages that the bearing and the force introduction into the permanent magnets 105a, 105b can be provided in the same plane, which results in considerable cost advantages in the implementation of the design. The arrangement of the push rods 111a, 111b is free of parasitic centrifugal forces, which would have to be neutralized in a complex manner by means of counterweights. By choosing a sufficiently large distance between the bearings 115a, 115b, it is also simple to decouple the magnetic effect

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of the coils 106.

Figures 5A and 5B1e shows a plan view and side view of a third embodiment of a main rotor of the aircraft according to the invention. The embodiment illustrated in Figures 5A and 5B1e is a variant of the main rotor control which can be implemented more easily, but which nevertheless has aircraft pitch/roll control capabilities. According to the illustration in Figures 5A and 5B1e, a coil 106, which is electrically connected via tap contacts (which are not illustrated), is mounted on the main rotor plate 103, which is connected to the main rotor shaft 108. Two rotary bearings 102 are likewise mounted on the main rotor plate 103, in which one, and only one, connecting bracket 101 is mounted, which rigidly connects the two rotor blades 104 to one another and to whose transverse cantilever ends a permanent magnet 105 and a counterweight 114 are fit. The permanent magnet 105 is arranged such that a direct current 107 through the coil 106 leads to deflection of the connecting bracket 101 and hence to a change in the angle of incidence  $\alpha$  of the rotor blades 104. In contrast to the embodiment shown in Figures 1A and 1Ba, the rotor blades 104 are, however, always deflected in opposite senses. If the coil current 107 is interrupted again, the centrifugal force of the connecting bracket 101, of the permanent magnet 105 which is attached to it and of the counterweight 114 counteracts the deflection, so that the connecting bracket 101 is reset back to a neutral position. Overshooting can be virtually completely avoided by fitting a fixed stop 109, which is not sprung, to the main rotor plate 103 underneath the connecting bracket 101. This principle can be utilized as follows for main rotor control: a force vector which is not coaxial with respect to the main rotor shaft 108 can be produced by applying an AC voltage whose period is synchronized to the speed of rotations of the main rotor shaft

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108. The embodiment which is illustrated in Figures 5A and 5B1e is a considerably simplified variant of the embodiment shown in Figures 1A and 1Ba. Instead of driving the collective blade pitch and aircraft pitch/roll, the embodiment which is illustrated in Figures 5A and 5B1e allows only the aircraft pitch/roll drive for the rotor blades 104. This embodiment is therefore dependent on the blade geometry of the rotor blades 104 producing a specific amount of lift depending on the speed of rotations, and hence corresponding to a fixed blade pitch angle. With regard to the pulse sequence for driving, the description of the aircraft pitch/roll drive can be used in conjunction with the embodiment shown in Figures 1A and 1Ba, as is illustrated in Figure 2B1b1i.

Since the collective blade pitch pulses are not superimposed, there is no need for any pulse correction, as described in conjunction with the embodiment shown in Figures 1A and 1Ba.

Figures 6A and 6B1f show a plan view and side view of a fourth embodiment of a main rotor of the aircraft according to the invention. In order to avoid sliding contacts, which in some circumstances are susceptible to defects, for producing an electrical connection to the coil 106 as shown in Figures 5A and 5B1e, the coil 106 shown in the illustration in Figures 6A and 6B1f is mounted in the non-rotating part of the helicopter. The connection between the rotor blades 104 and the permanent magnets 105 is in this case produced via the connecting bracket 101, the eye 110 and the (angled) push rod 111, to which the permanent magnet 105 is attached. The vertical force which is introduced by the push rod 111 via the eye 110 and the connecting bracket 101 leads to the already described deflection of the connecting bracket 101 and to the described control response. The resetting of the rotor blades 104 is ensured by replacing the weight of the permanent magnet

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105, which in practice is located on the rotation axis, by weights 112 which are provided on the outer areas of the connecting bracket 101. The damping of a damping element can be reinforced by mounting one of the counterweights 112 for overcoming the unbalance on the main rotor plate 103, and not on the connecting bracket 101. This means that the centrifugal forces produced by the individual weights 112, which are not compensated for, lead to increased bearing friction in the rotary bearings 102, which results in a damping effect with respect to deflection of the rotor blades 104. However, the increased bearing friction in some circumstances also leads to increased wear to the bearings 102. The embodiment shown in Figures 6A and 6B1f corresponds essentially to the embodiment shown in Figure 41d, with one of the push rods 111 with the associated arrangement comprising the permanent magnet 105 and the coil 106 optionally being omitted.

The present invention, in particular in conjunction with the features which are explained only in the description of the figures and may all be regarded as being significant for achievement of the object, is distinguished by the possible guiding structure, actuating elements which act completely digitally, and novel concepts for the integrated physical structure. This allows model helicopters to be produced at low cost, which are lighter in weight by a factor of about 10-20 than model helicopters based on conventional technology, with production costs that are the same or less. The small dimensions of the components as made possible by the invention mean that the bending torques which often have a destructive effect in the event of crashes are significantly less with respect to the strength of the components, so that the models based on the invention are at least just as robust as model helicopters constructed using conventional technology. The lighter weight also means that energy which is stored in the

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rotors during operation is considerably reduced, so that the risk of injury and damage is also significantly reduced, in comparison to conventional model helicopters, which are considerably heavier. The invention provides a remotely controlled aircraft which is particularly light in weight, weighing only a few grams, for example, when using currently available drive motors, but which nevertheless is reliable and can be subjected to loads. Furthermore, it is simple to convert the aircraft to other variants by virtue of a modular structure.

Although all the features relating to the following aspects are not claimed in the original application documents, the following aspect elements, in particular, are regarded as being significant to the invention:

- fully digital drive for the main rotor via magnetic slides
- fully digital drive for the tail rotor via digitally driven clutch or coupling elements
- fully integrated electromechanical gyro system
- newly designed landing gear, which operates on the spring-damper principle, with an integrated clamping apparatus, for example for the helicopter structure
- complete integration of all the actuating elements and measurement modules required for the function described above on one board, which can be clamped between the landing gear and the structure and carries out self-supporting functions.